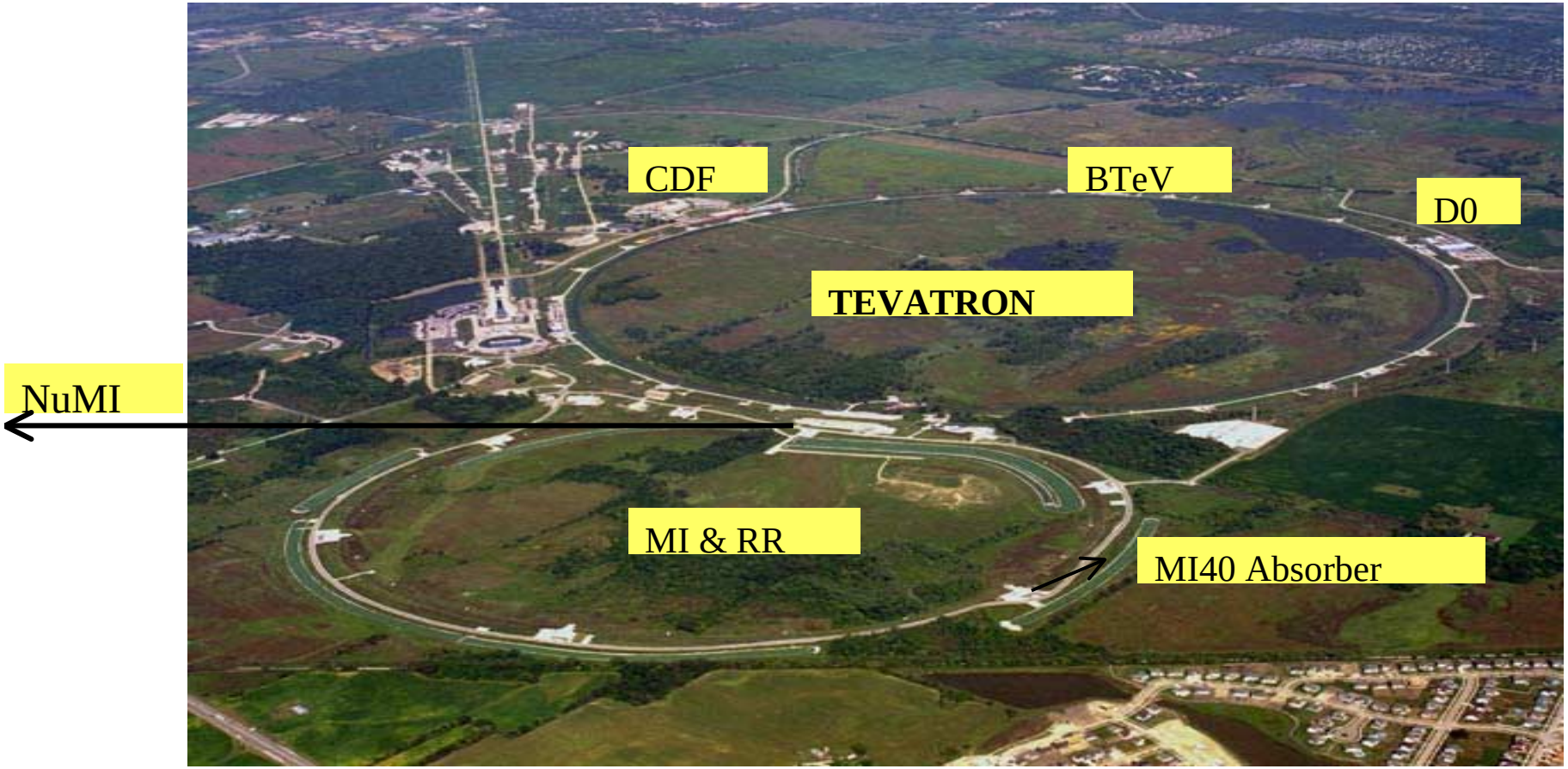
Pbar Deceleration in the Fermilab MI:
Tune-up studies with Proton Beam

C. M. Bhat

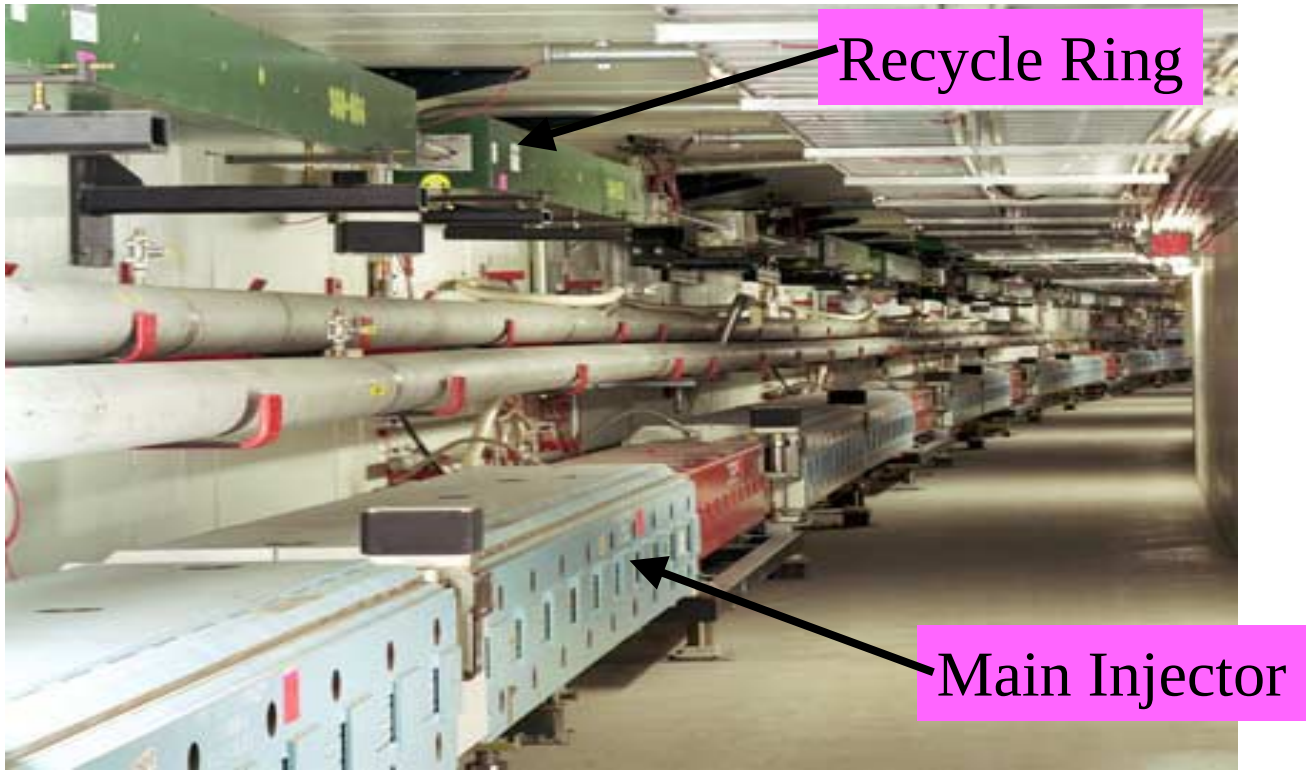
Main Injector, Beams Division, Fermilab

- Motivation
- Issues
- Deceleration Schemes in the MI
- Simulation Studies
- Experiments with Proton Beam
- Summary

Fermilab Site



Main Injector Tunnel



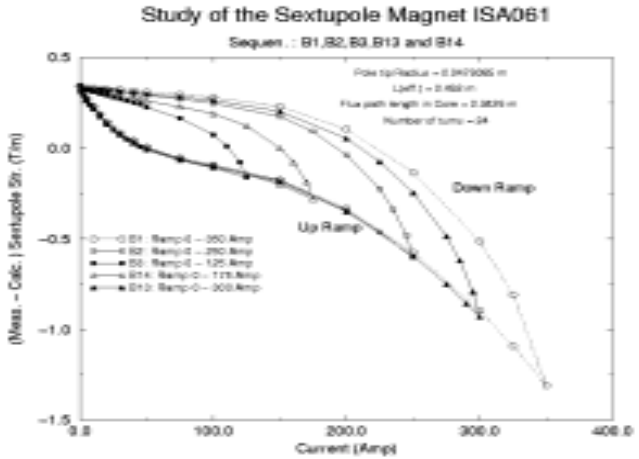
Why Decelerate pbars in MI

- Ultimate goal for Collider Run II is to provide an integrated Luminosity ≈**100 pb^{-1}/week**. This can be accomplished **ONLY** if we recycle unused pbars at the end of each Tevatron ppbar store.
  - About 40% of the pbars need to come from recycling.
- Recycling is achieved by decelerating the unused pbars first in the Tevatron from 1TeV to 150 GeV and then in the **Main Injector from 150 GeV to 8 GeV and transferring them to the Recycler Ring for cooling and for storage.**

Issues

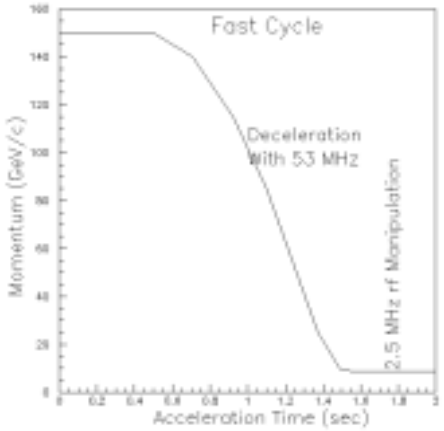
- Longitudinal Beam Dynamics:
  - Bunches from the Tevatron are typically 3-4 eVs in 53 MHz rf buckets. But the MI addimittance at transitioin is only 0.5 eVs. Hence we must do some rf manipulations during the beam deceleration from 150 GeV to 8.9 GeV.
- Transverse Beam Dynamics:
  - Hysteresis in Main dipole magnets and orbit correctors
  - Quadrupole Magnets
  - Sextupole magnets

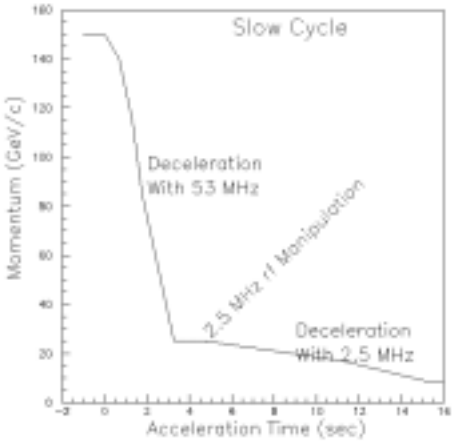
$\Rightarrow$ We had to develop a new corrector control program for the down ramp.



Deceleration Schemes in MI

- Scheme-I
  - Rotate a bunch in 2.5 MHz rf bucket and rebunch into several 53 MHz bunches
  - Decelerate 53 MHz bunches from 150GeV- 8GeV
  - De-bunch adiabatically using 2.5 MHz rf system
- Scheme-II
  - Decelerate pbars from 150 GeV to 25 GeV using 53 MHz rf system
  - Decelerate from 25 GeV to 8 GeV using 2.5 MHz rf system (to eliminate the transition loss and emittance growth)

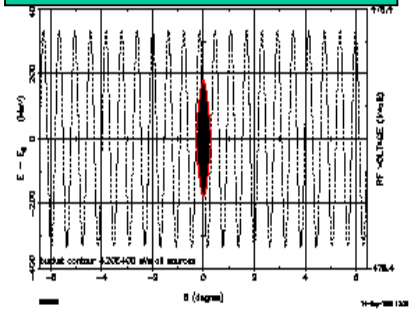




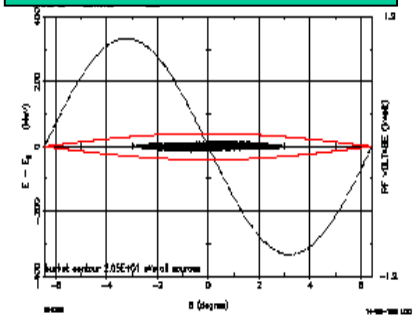
Longitudinal Beam Dynamics Simulations

Scheme-I

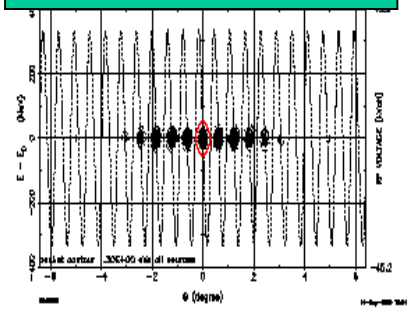
150 GeV MI Injection
h= 588 RF system



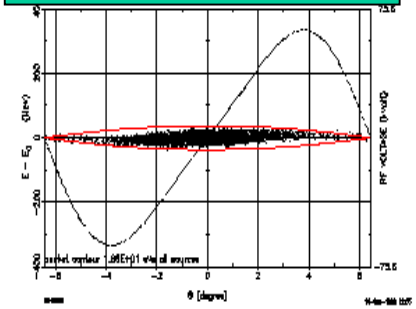
150 GeV,
Transfer to h= 28 rf system



150 GeV After bunching
with h= 588 RF system



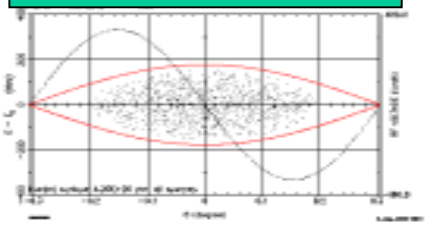
At 8 GeV, After Coalescing
in h=28 rf system



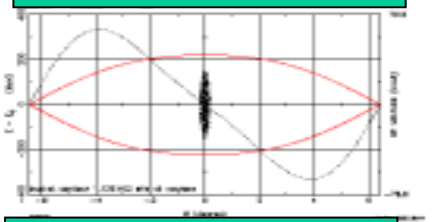
300% emittance growth
with 90% deceleration efficiency

Scheme-II

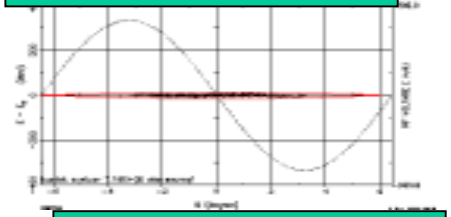
150 GeV, h=588



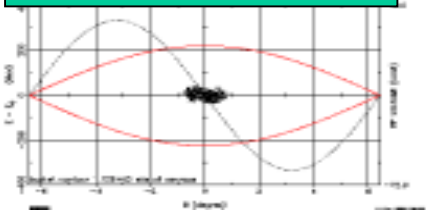
25 GeV, h=28



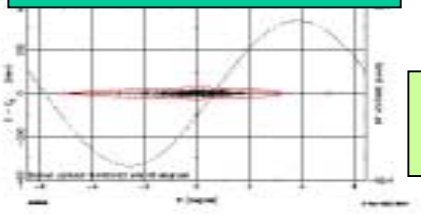
25 GeV, h=28
after bunch rotation



25 GeV, h=28,
after bunch shrink



8 GeV, before injection to RR



30% emittance growth with
100% deceleration efficiency

Comparison Between Two Deceleration Schemes

Pbar Deceleration Scheme I ** Deceleration with h= 588 system alone	Emittance (eV-sec)*	Efficiency
pbar Injection @150 GeV	3	100%
At 150 GeV After bunch Rotation	3.1	100%
At 150 GeV, After de-coalescing with h=28 & h=588 rf systems	5.2	100%
At 8GeV, After de-bunching with h= 28 rf system	8	89%

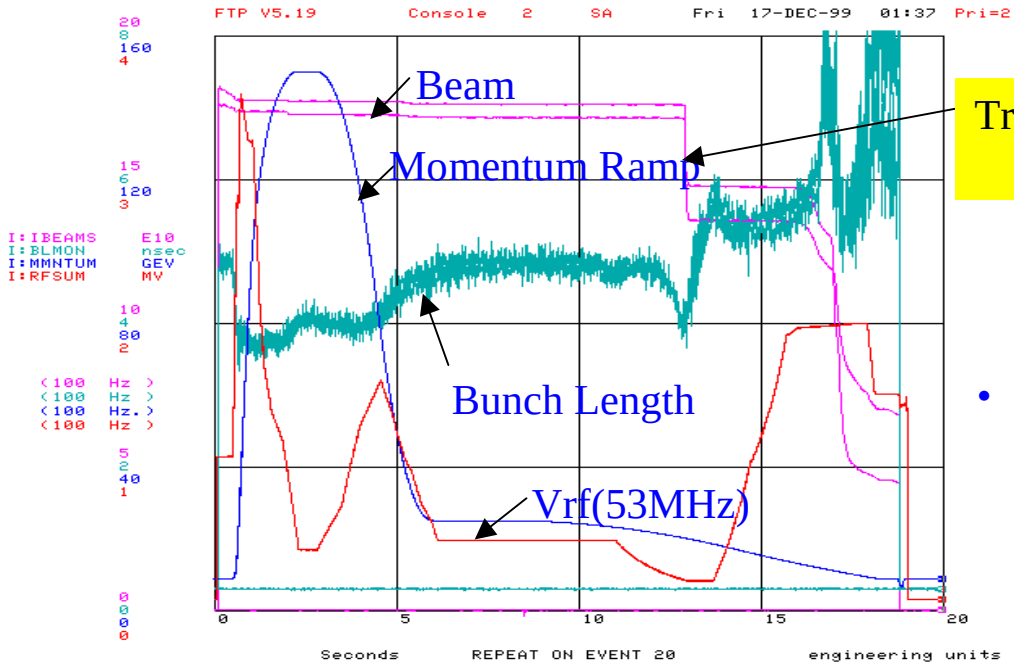
Pbar Deceleration Scheme II Deceleratioin with h=588 and partly with h=28 rf system	Emittance (eV-sec)*	Efficiency
pbar Injection @150 GeV	3	100%
At 25 GeV, After deceleration with h= 588 rf system	3	100%
At 25 GeV, After bunch rotation with h= 28 rf system	3	100%
At 25 GeV, After bunch shrinking with h= 28 rf system	3	100%
At 8GeV, After decelerating with h=28 system	3.8	100%

•RR Design Report specifies longitudinal Emittance of the in-coming beam to be 3-eVsec

** Simulations scaled to 3 eVsec initial emittance

Proton Deceleration in the MI from 150 GeV to 8 GeV

(with slightly mofified Scheme-II)_



- **Here the deceleration is carried out using only the 53MHz rf system (due to lack of hardware)**

Emittance Measurement

	Energy	BL	Emittance	Transverse Emittance(π-mi-mr)	
	(GeV)	(nsec)	(eV-sec)	H	V
Injection	8	5	0.1		
Flat-top	150	4	0.4	7	6
Back-porch	25	5	0.4	7	7
RR Injection Energy	8	7	0.8	8	8

Summary

- We have done first successful demonstration of deceleration of beam in the MI from 150 to RR injection energy
  - 100% efficiency from 150 to transition energy
  - 85% efficiency beyond transition energy (which should be ~100% with additional 2.5 MHz hardware)